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Heat exchanger and method for its manufacture.

The present invention concerns a recuperative heat exchanger for the transfer of heat between two media through a heat transferring wall, and a method of producing such a heat exchanger.

Heat exchangers are used for the transfer of heat between two media flows of different temperatures. In the conventional heat exchanger of so called recuperative type heat is transferred from the hot medium through a separating wall to the cooler medium. The design often comprises tubes inside which one of the media flows whereas the outer medium flows outside the tubes. This type of heat exchanger is often called tube-and-shell heat exchangers. It is also common practice to separate the media by means of more or less flat separating plates. This type of heat exchangers is often called plate heat exchangers.

If the heat exchanger is to serve its function of transferring heat it is important that the heat transfer surface area is as large as possible. This is often accomplished by dividing the media flows into multiple parallel part flows moving inside alternatingly juxtaposed passageways to form a unit with a large transfer surface area within a limited volume. The devices that are necessary for the separation of the flows into parallel streams are often complicated and expensive to produce. Often, the specifications for inter-flow leak sealing are stringent.

Except when subject to boiling or condensation the media change their temperature when passing through the heat exchanger. The temperature of the hot medium gradually decreases and the temperature of the cooler medium gradually increases. When the temperature difference between the media is small it is important that the flow geometry in the heat exchanger is such that the hottest part (the beginning) of the hot flow heats the

hottest part (the end) of the cool flow and that the coldest part (the end) of the hot flow heats the coldest part (the beginning) of the cool flow. Using such counter-current flow geometry in the heat exchanger makes it possible to achieve such a degree of heat exchange that the outgoing temperature of the cool flow is higher than the outgoing temperature of the hot flow. This is not possible when using a flow geometry where the media travel in the same direction through the heat exchanger, i.e. so called parallel flow heat exchangers.

To achieve optimum heat transfer in the heat exchanger it is necessary that the heat transfer between each medium and the separating wall is as good as possible. This can be accomplished by designing the separating wall in such a manner that it promotes the generation of a turbulent, well mixed, vortex filled flow in the medium that is in contact with the wall. Thus, when designing a heat exchanger there are three important objectives to consider, of which at least one and preferably all three should be accomplished. These objectives are:

1) Arrangement of each flow to be distributed over several parallel passageways in such a way that the passageways are alternatingly in juxtaposed relationship so as to have a large total heat transfer surface area.

2) Heat transfer walls in the heat exchanger that contribute to the generation of a turbulent flow with good heat transfer to the wall.

3) Counter-current flow of the media in the heat exchanger.

These objectives can be difficult to achieve. Especially objectives number 1 and 3 have proved difficult to achieve at the same time without causing high costs.

The present invention relates to a heat exchanger wherein all three objectives are met simultaneously while the costs are kept low.

The invention will be described in the following in closer detail by way of an example with reference to the accompanying drawings, wherein:

FIGURE 1 in a perspective view shows important steps of the manufacture of a heat exchanger according to the present invention.

FIGURE 2 is a perspective view of a heat exchanger according to the invention depicted in a not fully closed state in order to show the internal flows of the media.

FIGURE 3 is a perspective view of a part of the heat transferring walls in the same heat exchanger.

FIGURE 4 is a perspective view of a heat exchanger according to the invention in accordance with a slightly different embodiment and shown in a not fully closed state.

A heat exchanger according to the invention preferably is produced as shown in Figure 1 from a continuous sheet 1 of metal, plastic or other suitable material which in the completed heat exchanger will serve as a heat transferring wall. In Figure 1 numeral references 2 and 3 denote rollers between which the sheet is fed in the direction of arrow 4. The surfaces of the rollers are formed with patterns of oblique ridges and grooves 5 and 6. Furthermore, the rollers are formed with ridges 7 and grooves 8 extending in parallel with the roller axis. Every ridge 7 corresponds to a groove 8 on the opposite roller. Accordingly, when the sheet passes between the rollers, the ridges 7 and the grooves 8 form folding lines 9 in the sheet. Since in sequence along the circumference of each roller a ridge 7 is followed by a groove 8 the folding lines will be pressed alternatingly in one and the other of the opposite sides of the sheet. This makes it easy to fold the sheet at the folding lines into a package 10 comprised by a number of juxtaposed layers. The oblique pattern 5 and 6 on the rollers gives the band a corrugated configuration best visible in the encircled enlargement 11 in Figure 1. The sheet is cut to suitable lengths so that

an appropriate thickness of the package 10 is obtained. In Figure 1 a complete finished package is represented by numeral 12. The ends of the package 12 are closed by covering elements 13 which may be produced for instance by dipping the package ends into a compound that is soft from the beginning but after a while solidifies when cooling or by chemical reaction. Numeral reference 14 relates to a sealing strip which is applied to one side of the package, e.g. the bottom part. A corresponding seal, not visible in the drawing, is applied to the opposite side of the package. Numeral reference 15 denotes a box-shaped casing 15 generally, into which the package 12 is intended to be placed as indicated by arrow 16. When the package is thus placed inside the casing, the seal 14 will be forced against the bottom of the casing and the covering elements 13 will seal against the end walls 17 and 18 of the casing. Preferably, the width B of the package 12 essentially corresponds to the spacing between the side walls 19 and 20 of the casing while the height H of the package essentially corresponds to the height of the casing. The casing 15 has a lid 21 the shape of which matches that of the open upper side of the casing 15 in Figure 1. At the corners of the casing 15 connecting ports 22 - 25 are arranged. The connecting ports 22 and 25 serve as inlet and outlet ports respectively for one of the media and connecting ports 23 and 24 serve as inlet and outlet ports respectively for the other medium. When the lid 21 is fitted while the package 12 is in the casing 15 the lid will seal against the top face of the package 12. The sealing strips 14 and the covering elements 13 prevent the two media from mixing and thus the media are kept separate, one on either side of package 12 and thus on either side of the folded sheet. Figure 2, for the sake of clarity showing the upper part of the package slightly raised, illustrates the flow paths of the two media. The directions of flow are shown by arrows 26 for one of the media and with arrows 27 for the other medium. As is most

clearly apparent from Figure 3 the corrugations in one layer of the folded sheet will extend crosswise with respect to the corrugations in the next layer. These crossing corrugations formed in the facing sides of adjacent layers create a turbulent flow in the medium flowing between the layers. To a considerable extent, this will contribute to an efficient exchange of heat between the two media.

In the example shown the sheet is given a corrugated pattern but whithin the scope of this invention shaped patterns of different configuration that create turbulence in the inter-layer space may also be used. In the example shown the shaped pattern was made by means of rollers, but the shaped pattern can also be accomplished by stamping. As mentioned above, the covering elements 13 are made of a solidifying compound. However, it is within the scope of the invention to produce the covering elements 13 as separate lids which with an intermediate soft layer that is pressed against the ends of the package. It is also possible to use layers of soft material between the ends of the package and the end walls of the outer casing. The casing 15 and the lid 21 thus form an outer shell that together with the seals 13 and 14 on the package 12 constitutes an efficient media flow separating and sealing means. The seal shown in the figures could however, be made in a very simple and inexpensive manner. The application of the sealing compound or other soft material can be made without high precision or geometrical exactness. A sealing effect could also be accomplished by a good fit only or by soldering or welding when suitable materials, therefor are used.

In contrast to the example described above, wherein a casing 15 with a lid 21 forms a shell around the package 12, this shell is formed according to Figure 4 by a box 28 having a rectangular cross sectional shape. On one side, the box is equipped with an inlet port 29 and an outlet port 30 for one of the media and on the other side with an

inlet port 31 and an outlet port 32 for the other medium. In this example the package 12 is inserted through one open end of the box which thus forms a casing 33 which may be closed by lids 34 and 35. The lids 34 and 35 are designed to seal against the ends of the package 12, either by themselves or by means of intermediate sealing layers. The lower lid 34 in Figure 4 could for instance be fastened by means of a liquid sealing compound which is poured into the lid and which solidifies after the assembly 28, 12 has been dipped into it. The other lid 35 can then be fastened in the same way after the assembly 28, 12 having been turned upside down. This kind of moulding can also be used in the example shown in Figures 1 and 2. When using an appropriate sealing compound the lids may be removed after the moulding operation and thus only serve as moulds in the moulding process.

The shaped pattern in the sheet serves at least three purposes. One is to establish a certain distance or pitch between successive layers in the folded sheet so that a medium can flow in the inter-layer space. The shaped pattern should also promote turbulence in the flow as described earlier.

The simple pattern described above serves both these purposes. As mentioned above, after folding of the sheet the oblique corrugations form a system of crossing ridges. The ridges maintain a certain spacing between the different folds and produce a tortuous, turbulence-inducing flow path for the medium which, as mentioned above, promotes heat transfer to the wall.

Owing to the design of the heat exchanger, the two media flows are distributed over a number of parallel channels that are placed in alternating nesting position. The third purpose of the shaped pattern is to achieve an evenly distribution of the flow sideways within and across each channel. Thus an essentially counter-current flow pattern is established between the two media flows even when their inlet and outlet ports do not extend in the

prolongation of the flow direction.

An efficient lateral spread of the flow of this kind is achieved if the resistance to flow sideways is lower than the resistance of flow lengthwise in the channel. This result is obtained with the proposed simple corrugation of the sheet if the angle of the corrugations to the longitudinal extension of the sheet is less than 45°, or differently expressed, if the angle of the corrugations to the intended direction of flow is more than 45°.

The simple corrugation pattern which has been used as an example above is easy to produce between two helically cut rollers as in Figure 1. It is also well suited to fulfill the objects of keeping the spacing between the layers, and of promoting turbulence and lateral distribution of the flow as have been discussed above. Many other stamped patterns are also possible, as mentioned above. To facilitate the folding of the sheet the corrugations preferably could be interrupted and be replaced by folding lines at suitable spaced-apart intervals as shown in Figure 1. Another improvement of the pattern would be to provide the inlet and outlet areas (the outer parts of the sheet) with a different pattern from the main part of the sheet area so as to give an efficient lateral distribution of the flow without making the lengthwise resistance to flow too high in the main part of the heat exchanger. A reduction of the resistance to flow in the heat transferring part of the heat exchanger most often however invovles a reduction of the heat transfer there, which is not desirable.

The invention is not limited to the above described examples but can be varied as to its details within the framework of the following claims without departing from the scope of protection of the invention.